POSSIBLE DETECTION OF FLARE-GENERATED POSITRONS BY HELIOS 1 ON 3 JUNE 1982

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1. Introduction. The production of neutrons and γ-ray lines by solar particles in the photosphere has been studied by (1,2,3) and others. In the meantime γ-line measurements were reported (4,5,6,7). The principal positron emitters which lead to the 0.51 MeV γ-line are ^{11}C, ^{14}O, ^{15}O, ^{13}N, ^{19}Ne. The energies of the positrons from radioactive nuclei are of the order of few hundred keV. Positrons resulting from the π^+ decay have energies of $\sim$ 10-100 MeV and cannot be measured by the MPAe-detector.

Most of the positrons annihilate in the photosphere. A fraction however should be able to escape into the interplanetary space (2). It is the purpose of this paper to present proton, electron and, for the first time, positron measurements (E = 152-546 keV) obtained by the MPAe-particle detector on board of Helios 1.

2. Experiment description and method of detection. The MPAe-detector was designed to measure ions (E $\geqslant$ 80 keV), electrons (E $\geqslant$ 20 keV) and positrons (E = 152-546 keV) with high energy (16 channels) and angular (16 sectors) resolution (8,9). Ions, electrons and positrons are separated by a inhomogeneous magnetic field and then detected by several semiconductor detectors. S_7 (125 mm² area, 322 μ thickness) is the ion detector and S_8 (300 mm², 274 μ) its anticoincidence detector. The positron detector S_6 (200 mm², 1000 μ) is anticoincidence shielded by S_9 (300 mm², 322 μ). A fully anticoincidence shield was not possible due to weight limitations. Various coincidence conditions lead to the following channels: $S_{6.1} \cdot S_{6.2} \cdot \overline{S_9} = e^+$ (152-546 keV); $S_{6.1} \cdot S_{6.2} \cdot \overline{S_9} = e^+$ (>546 keV), $S_7 \cdot \overline{S_8} = p$ (> 80 keV) and x,γ rays, $S_7 \cdot S_8$ = p,e ($\geqslant$ 6 MeV); S_9= p,e $\geqslant$30 MeV) and x,γ-rays; $S_{1,2,3,4} = e^-$ ($\geqslant$ 20 keV) and x,γ rays. The x and γ-ray sensitivity results from the Compton scattering process of photons in the detectors. In interplanetary space positrons must be identified in the presence of relativistic particles, x and γ-rays and high energy neutrons produced by the same flare.

3. Observations. The 2B white light flare (S 09°, E 72°) on 3 June had its optical emission from 11:41 - 13:26 UT (Hα max = 11:48 UT) and produced X rays (Solar Geophysical Data, June 1982), γ-rays and neutrons (6). Helios 1 was at a distance of 0.57 AU from the sun and at $\sim$99° heliographic longitude i.e. well connected to the flare region. The time resolution of the measurements was 107 sec. Fig. 1 shows from top to bottom $\geqslant$30 MeV protons and electrons (S_9), $\geqslant$ 6 MeV protons, electrons ($S_7 \cdot S_8$) and measurements of the 2 positron channels. It can be seen that the positron channels are disturbed by particles which penetrate the shielding of the instrument and cannot be eliminated by the anticoinci-

dence detector S_9. Thus the only chance to separate positrons against the background exists before the main increase. The low energy positron channel has a small premaximum followed by a short minimum (Fig. 1). The increase phase is shown in Fig. 2 with 107 sec time resolution. The main event starts to increase in intervals 4, 5 and 6 and only interval 4 may be suitable for a possible positron identification. If we take the maximum of the radio burst (Solar Geophysical Data, June, 1982) 11:43:20 UT at earth (minus 500 sec at the sun) as the start of the nuclear interaction and the production of the positron emitters the first positrons of 150-550 keV will be expected ∿ 425-310 sec later at Helios, i.e. 11:40:10 - 11:42:05 UT which is interval 4 of Fig. 2.

From other observations it is known that the event starts with a γ and x-ray peak (6) which is in time coincidence with interval 3 of Fig. 2. About 100 sec later (corresponding to interval 4 and 5 of Fig. 2 the x ray and 4.1-6.4 MeV γ-line flux is smaller by approximately a factor of 10. However the delayed γ-ray lines (2.2 MeV see (10 their Fig. 1) and 0.51 MeV see (11 their Fig. 6)) contribute to the background of interval 4 and 5 of Fig. 2 and must be eliminated. The curves 1 and 2 (Fig. 2) present measurements of the electron detectors for the solar (1) and antisolar (2) direction. Different operation modes of the ion detector ($S_7 \cdot \overline{S_8}$) are shown in curves 3-6 for the solar (3,5) and antisolar (4,6) direction which measure the x and γ-ray background in this early phase. Curve 7 presents protons, electrons and γ-rays measured by the single detector S_9 whereas curve 8 (S_7 S_8) shows the increase phase of charged particles. Thus charged particles and γ-rays contribute to the count rate of the positron channels also in interval 4 (curves 9,10). In comparison to the pre-event intervals (I_o, I_1, I_2) the interval 4 shows the following increases

1) p, γ, ($S_7 \cdot \bar{S}_8$, $\Delta E \geqslant 80$ keV), curve 5 and 6

$$I_4/(I_1 + I_2)/2 = \frac{182}{133} = 1.368$$

2) p,e,γ, (S_9, $\Delta E \geqslant 80$ keV), curve 7

$$I_4/(I_o + I_1 + I_2)/3 = \frac{816}{645.33} = 1.264$$

3) e^+,p,γ ($S_{6.1} \cdot \overline{S_{6.2}} \cdot \overline{S_9}$, $\Delta E = 152 - 546$ keV), curve 9

$$I_4/(I_o + I_1 + I_2)/3 = \frac{106}{65} = 1.63$$

The second positron channel (curve 10, $\Delta E \geqslant 546$ keV) will not be considered since the magnetic system of the experiment does not quantitatively deflect the positrons of such energies.

By comparing the proton (5+6) and the positron channel (9) it follows that 1.368/1.63 = 0.839 of the positron count rates results from background radiation. The positron count rate in interval 4 would then be

$$106 - 0.839 \quad 106 = 17 \pm 14$$

(14 = statistical error calculated after quadratic error propagation). The flux above the statistical error may be considered as positrons. It follows for a geometric factor of G = 3.2 10^{-2} cm² sterad and 107 sec measuring time

$$\frac{3}{107 \quad 3.2 \quad 10^{-2}} = 0.876 \ e^+/\text{cm}^2 \text{ sec ster}$$

or extrapolated to 1 AU distance = 0,28 e^+/cm^2 sec ster. It is assumed that positrons are confined by the interplanetary magnetic field to, say $\sim$1 sterad. The same flux distributed over 2 π steradian would then be 4.4 10^{-2} e^+/cm^2 sec ster. Model calculations (3; their fig. 5) reveal that about 40 % of the positron emitters have decayed in $\sim$100 sec. The totally emitted positron flux is therefore $\lesssim$ 11 e^+/cm^2.

4. Discussion and conclusion. The flare of 3 June 1982 has been investigated by (6,10, 11). It is of interest to compare the flux of the emitted positrons with the flux of totally generated positrons. After Share and Rieger (private communication) the time integrated flux of the 0.51 MeV line was $\sim$100 γ/cm^2. According to (11, their fig. 6) the flare of 3 June 1982 has a high $\alpha \cdot T$ value (α = stochastic acceleration efficiency of the flare region, T = particle residence time in the acceleration region) namely $\alpha \cdot T = 0.04$. For such an $\alpha \cdot T$ a ratio of the generated positrons to the 4-7 MeV γ flux of

$$\frac{e^+}{4\text{-}7\ \mathrm{MeV}} \sim 0.7$$

can be derived from (3, their fig. 4). From the 4-7 MeV flux of 305 photons/cm² (11) follows then 213 e^+/cm^2 have been generated.

A further possibility to calculate the flux of the positrons is to compare the total proton flux $\geqslant$ 30 MeV of $3 \cdot 10^{33}$ protons (11) with model calculations of (3, their fig. 5). It follows $\sim 5.5 \cdot 10^{-32}$ $3 \cdot 10^{33}$ = 165 photons/cm² (when $\alpha\tau = 0.02$) and more than 165 would be expected for $\alpha\tau = 0.04$.

Thus assuming the "thick target" interaction model and the here derived positron flux (11 e^+/cm^2) it can be concluded that $\leqslant$ 10 % of the positrons can escape into the interplanetary space.

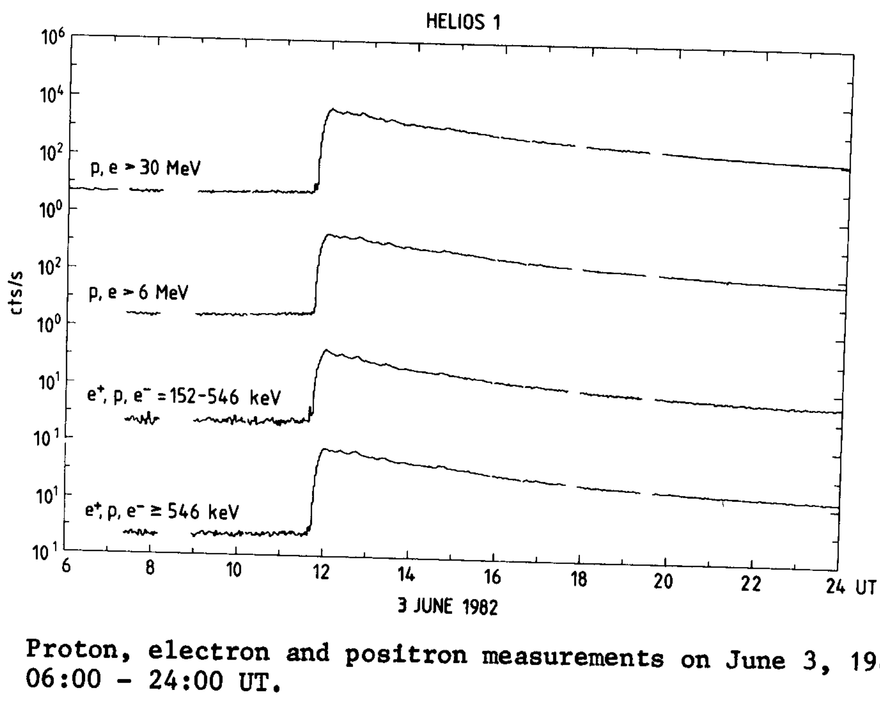

Fig. 1 Proton, electron and positron measurements on June 3, 1982, 06:00 - 24:00 UT.

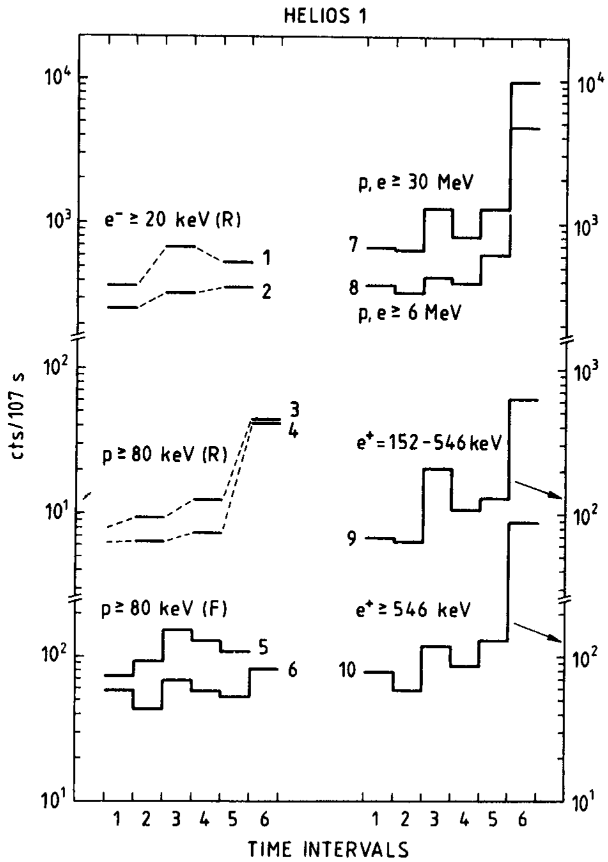

Fig. 2 Increase phase of the June 3, 1982 particle event.

Interval 1 = 11:35:24 UT
2 = 11:37:11 UT
3 = 11:38:58 UT
4 = 11:40:45 UT
transmit time
5 = 11:42:32 UT

ΔT = 107 sec

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